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EXPLORATORY LASERS

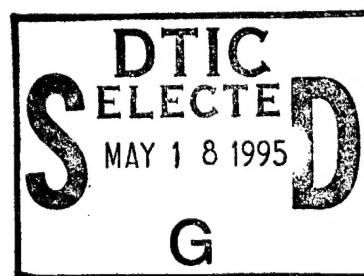


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Final Report for Workunit 20010501

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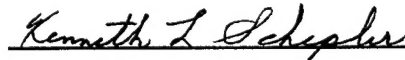
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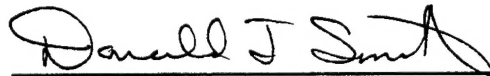
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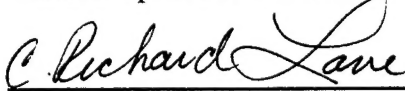
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13. ABSTRACT (Maximum 200 words) This document is the final report for work unit 20010501. The objective of this work unit was to improve performance of existing lasers and to demonstrate new laser source concepts in line with Air Force mission needs. Technical accomplishments are briefly reviewed with references to more detail in previous publications.				
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Dr. Gary Catella	Cleveland Crystals, collaboration
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The start of this workunit marked the transition from research on gas and chemical laser to research on solid-state lasers at this laboratory. The problems with size, reliability, and safety in gas and chemical lasers had become evident from previous research efforts. Solid-state lasers offered the potential of smaller size, less complexity, higher reliability, and fewer safety issues. In addition, the potential of developing tunable solid-state lasers offered important advantages in many new applications, both military and commercial.

2. TECHNICAL ACCOMPLISHMENTS

This final report is a brief overview of the research done under workunit 20010501. For detail on a particular area, the papers referenced in the text below and listed in the Appendix may be consulted.

Efforts throughout this program concentrated on the investigation of solid-state lasers with wavelength tunability or wavelength conversion. In-house measurements ranged from basic spectroscopy to performance assessment of commercial laser devices. Emphasis was placed on measurement and evaluation of those properties which could be used to assess the potential of a particular laser medium, nonlinear material, or innovative concept. Air Force requirements in the areas of operating wavelength, efficiency, output power/energy, reliability, maintainability, and safety were the motivating criteria.

Early work concentrated on the investigation of laser crystals doped with transition metal ions. Transition metal ions were found to have broad, continuously tunable output due to the coupling of their electronic energy levels to crystal vibrational levels. Alexandrite was an early success with useful tunability in the 730-780 nm range.[1] Other chromium-doped crystals were investigated but most of them were found to have severe problems with solarization under flashlamp pumping. This resulted in poor

laser performance.[2,3] Investigations of other ions such as Sm^{2+} [4] with the potential for lasing at several lines were also pursued.

Titanium-doped host materials were shown to have great promise as tunable visible lasers.[5] Indeed, titanium sapphire has become a great success with tunability throughout the 700-1000 nm range and with numerous commercial devices now available. However, temperature dependent spectroscopic investigations of titanium doped into other crystal hosts [6-10] showed that sapphire had an optimum crystal field strength. In hosts with weaker crystal fields, the nonradiative losses became severe at room temperature. In hosts with stronger crystal fields, such as YAlO_3 , gain was not observed possibly due to excited state absorption into the conduction band of the host lattice.

Co-doping of chromium and neodymium in garnet hosts was investigated.[8,11] Cr^{3+} ions were found to be more efficient absorbers of flashlamp radiation than rare earth ions such as Nd^{3+} . In certain garnet crystals co-doped with Cr^{3+} and Nd^{3+} ions, chromium ions efficiently transferred their excitation to neodymium ions resulting in flashlamp pumped laser efficiencies approaching 10%, twice that of Nd:YAG. However, garnet crystals with efficient energy transfer were also found to have thermal lensing at least twice as strong as YAG.

In the late 1980's emphasis was placed on development of a

tunable, mid-IR laser useful for infrared countermeasures. Because they operated only at discrete wavelengths, rare earth lasers alone did not meet the tunability criterion. However, nonlinear frequency conversion appeared to be a viable solution.[12,13] For that reason considerable effort was devoted to the characterization and development of optical parametric oscillators (OPO's) and difference frequency mixers capable of generating 2-5 μm tunable output. AgGaSe_2 was shown to work well as a mid-IR OPO pumped at 2 μm with conversion efficiencies near 30% at kilohertz repetition rates and output powers approaching 1 W.[14-18] However, at pump powers above 4 W, AgGaSe_2 was found to have severe thermal lensing problems which prevented scaling to output powers greater than 1 W.[19,20] In addition, surface damage limited energy densities that could be safely applied to an OPO crystal surface.[21]

Modeling of nonlinear interactions was done to better understand and improve upon the limitations of current frequency conversion techniques.[22] Although the basic theory is known, the details of threshold and conversion efficiency are still poorly understood.

Nonlinear interactions using 1- μm laser pumping, both difference frequency generation and OPO's, were investigated as an alternative to 2- μm pumped frequency conversion.[23-25] Use of a 1- μm Nd:YAG pump laser has the advantage of using well-

developed pump laser technology. Also, the KTP-type nonlinear crystals have been shown to be more damage resistant than chalcopyrites like AgGaSe_2 . Efficient conversion has been demonstrated but generation of emission beyond $4\text{ }\mu\text{m}$ with available nonlinear crystals has not been possible due to absorption features at long wavelengths.

3. CONCLUSIONS

The technical accomplishments of this effort have had a major role in developing solid-state lasers to meet Air Force needs. Solid-state tunable visible lasers are now commercial devices. And breadboard lasers capable of efficient generation of mid-IR output have been demonstrated.

However, the battle is clearly not over with victory declared on all fronts. A number of important issues remain to be addressed, particularly the need for a high average power, high repetition rate, tunable mid-IR laser for a number of Air Force applications. Efforts to advance this technology will be continued under the auspices of an AFOSR-funded Infrared Countermeasures Initiative. Results will be documented under workunit 2301EL01.

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